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An IoT Based Health Monitoring System Design, Hardware Implementation and Testing

Arjoon Chatterjee[1], Ayan Ghosh[1], Abhishek Kumar[1], Prashant Kumar Tiwari[1], Priyotosh Garai[1], Somya Singh[1], Malay Ganguly[1] Suchismita Banerjee[2], Shinjini Mukherjee[3] and Ashoke Mondal[2]

[1]Department of Electronics and Communication Engineering, Institute of Engineering & Management, Kolkata, India
[2]Department of Electronics and Communication Engineering, RCC Institute of Information Technology, Kolkata, India
[3]Department of Electrical Engineering, RCC Institute of Information Technology, Kolkata, India

ABSTRACT

The onset of Covid 19 Pandemic has posed significant challenges and risks to the health sector globally. Hospitals and healthcare facilities faced challenges in managing the influx of patients leading to strained resources. The demand for medical supplies, personal protective equipment (PPE), testing kits etc surged and the shortage of these had a massive impact on the health of the healthcare workers, compromising their ability to pay adequate care to their patients. As a result, more people get affected leading to shortage of workers and adverse health conditions. Also, the PPE kit which is a onetime use equipment is made of plastic liners and polypropylene which when disposed will add to plastic waste and is thus hazardous to the environment. Affordable hardware prototypes with embedded software and IoT for sensor measurements have been developed, yet their costs remain prohibitive for widespread adoption in developing countries.

In this research paper we have proposed a system that includes remote patient monitoring, real time data analysis, and secure communication channels to ensure the confidentiality of sensitive health information using IOT. This not only ensures safe and efficient healthcare services but also empowers individuals to actively participate in the health management. Through this we aim to contribute towards the integration of IOT in healthcare, emphasizing the use of technology to improve patient outcomes, optimizing resource utilization and advancing the paradigm of modern healthcare delivery.

KEYWORDS

IoT; Remote Monitoring; COVID-19; ESP8266; Oximeter; Thermometer; Pulse Measurement;

1. INTRODUCTION

Proper health Monitoring is very much essential especially during the time of pandemic as we have seen in the case of Covid 19 [5]. Timely and accurate monitoring of patient health status is crucial for early detection and isolation of cases and providing appropriate medical interventions. Till date lots of facilities are available like pulse oximeter, respiratory monitors, ECG monitors etc, which can track the health. The existing protocol for health monitoring in hospitals often necessitates the physical presence of healthcare workers to conduct necessary device setup, data retrieval, and monitoring procedures for each patient. This reliance on in-person interactions poses a significant drawback, as it increases the risk of healthcare workers contracting infections, potentially leading to workforce shortages and operational instability within healthcare facilities. [6, 45]

As a proactive solution to address this challenge, we have proposed the implementation of a system capable of remotely monitoring patients' vital signs, including SpO2 levels, heart rate, and temperature. In a smart healthcare system, using automation and IoT technologies was proposed.[13] This innovative approach not only minimizes the risk of infection, but also mitigates the escalating demand for health care workers. Moreover, the proposed system enables simultaneous monitoring of data from multiple patients, enhancing overall efficiency in healthcare delivery.[7] Communication has been done between sensors, controller, and other peripherals of the device.MAX30100 sensor module and OLED display is embedded with Node MCU controller via Inter Integrated Circuits (I2C) communication [3, 13]. Subsequently, the NodeMCU efficiently transmits the collected health data to the designated IoT cloud platform, establishing a robust infrastructure for remote health monitoring [1, 2].

2. PROPOSED SYSTEM

Figure 1 shows the block diagram of the proposed IOT based Health Monitoring System. It consists of two sensors, the MAX30100 which is the oximeter and measures the SpO_2 level of the blood and the heart rate, the DS18B20 which is the temperature sensor and is used to measure the body temperature [8, 43].

These data from the sensors are displayed on the OLED. The power circuit also consists of external power supply [3]. For Internet connectivity of the main controller Wi-Fi routers are used although which can be easily replaced by Wi-Fi Dongle, Jio-Fi Devices or Mobile Hotspot from any cell phone with network connectivity. Which makes the device very much versatile to use. Data sent to cloud for storage and remote monitoring through the Blynk app [2]. Powering the device is also a simple process. The whole control system runs on 5V power supply which can be given from external source [4].

Hence A 5 Vdc adaptor USB micro-B type is required to power up the device. This voltage level allows versatile power supply range. The device can be power by any 5 Volts 1 Amps adapter, Power Banks or any USB port. Some of the hardwires run on 3.3V power supply and SMD 3.3 voltage regulator takes 5V as input and supplies power to those hardwires [4, 43].

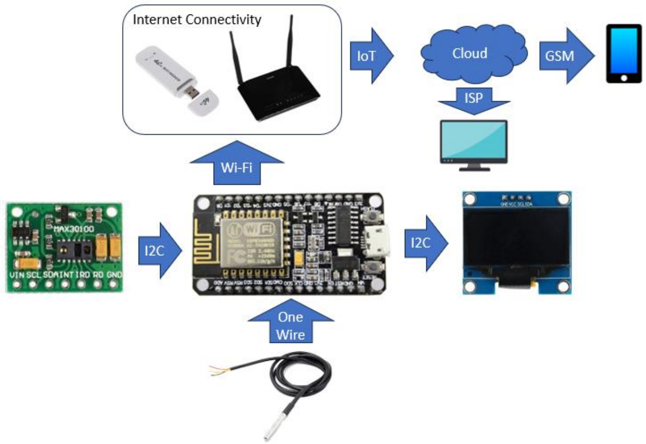


Fig. 2 Proposed System Block Diagram

The MAX30100 pulse oximeter is a versatile sensor capable of simultaneously measuring heart pulse rate and blood oxygen levels.

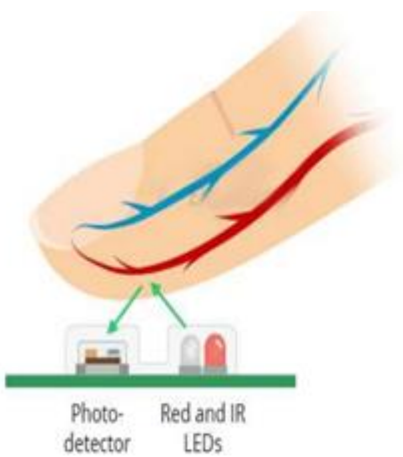


Fig. 3 MAX30100 Sensor Working Principle

Figure 3 Shows The red light emitted by the LED is utilised for pulse rate measurement, by detecting variations in reflected light by the Photodetector the volume of oxygenated blood with each heartbeat is measured. The photodiode in the sensor captures and measures the change in light intensity, enabling accurate calculation of pulse rate through temporal variation analysis. [14]

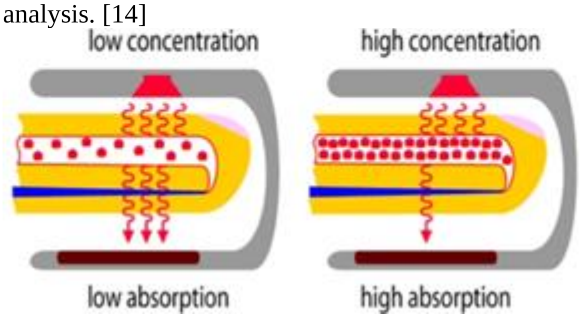


Fig. 4 MAX30100 Sensor Working

For oxygen level measurement, both LEDs are employed. Oxygenated blood absorbs more infrared light and allows red light to pass through, while deoxygenated blood exhibits the opposite behaviour. As shown in Figure 4 The photodiode measures changes in light intensity, and the resulting signals are processed through an analog-to-digital converter [45], providing output data via I2C serial communication protocol [2][24].

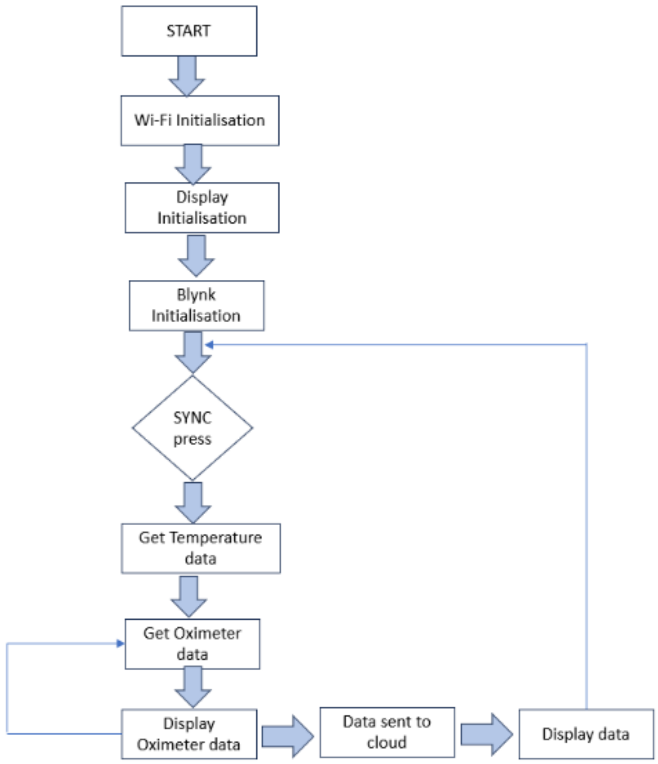
Fig. 5 DS18B20 Temperature Sensor

The DS18B20 is the temperature sensor, offering temperature readings ranging from 9 to 12 bits. Employing a 1-Wire communication method, this sensor interfaces seamlessly with microcontrollers. It is fairly precise and can measure temperatures from -55°C to +125°C with ±0.5°C Accuracy [10]. Comprising two integral components, one dedicated to data measurement and the other, a fundamental chip, responsible for analog-to-digital conversion, the DS18B20 produces a digital signal reflecting the temperature [44, 13]. This streamlined communication and internal processing mechanism makes DS18B20 an efficient and reliable solution for temperature sensing applications [25].

These sensors are connected to the NodeMCU which is an open-source IoT platform. It includes firmware that runs on the ESP8266 Wi-Fi system on a chip and is programmed using the Arduino IDE [26]. The data from the sensors are fetched by the NodeMCU which is also displayed in the OLED which is an array of light-emitting diodes (LED) in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current [27].

3. SYSTEM ALGORITHM

In We begin by supplying 5V DC power to the NodeMCU, subsequently energizing both the OLED and the MAX30100. The initialization sequence encompasses Wi-Fi and Display Initialization, succeeded by the initiation of Blynk, a cloud platform integral to this project. Blynk facilitates remote control of the hardware, storage, and visualization of sensor data. Following this, we engage the Sync button to refresh the system and place our finger on the oximeter sensor, simultaneously holding the temperature sensor with the other hand. This yields temperature data, SpO_2 level, and heart rate data. The OLED, directly connected to it, prominently displays the heart rate and SpO_2 data. All sensor data is seamlessly transmitted to the Blynk Platform in the cloud, where it is visualized. Furthermore, the system issues alerts if the values deviate from the norm, prompting the user to take necessary precautions. The entire procedure can be elucidated through the accompanying flowchart diagram.



4. DATA ANALYSIS

The body temperature chart at Table 1 shows our body condition during normal state Hypothermia or Hyperpyrexia [31]. The following data is fed into the programming as the reference. Fahrenheit scale is used to display the body temperature.

Table. 1 Body Temperature Chart

Body Temperature	State
98.6°F – 99.5°F	Normal
<95°F	Low
>100.5°F	High

$$Temperature\ (°C) = \left[\frac{ADC\ Value * 5}{4095} - \frac{400}{1000}\right] * \frac{19.5}{1000}$$

The temperature can be converted into Celsius scale from above expression.
On the other hand, the pulse rate is determined as unit Beats Per Minute (BPM). The digital pulses are given to a microcontroller for calculating the heat beat rate, given by the formula [2]:

$$BPM\ (Beats\ per\ minute) = 60 * f$$

f = Pulse Frequency

Table. 2 Pulse Rate Chart

Body Temperature	State
60 BPM – 100 BPM	Normal
<60 BPM	Low
>100 BPM	High

As per “Pulse Oximetry Training Manual. World Health Organization” the reference oxygen level for healthy personals is integrated into the device for accurate alert generation.[30]

Table. 3 Oxygen Level Chart

SpO2	State
94- 100	Normal
<94	Low saturation
<90	Critical emergency

5. HARDWARE AND APPLICATION SETUP

The Devise is kept inside an enclosure with and entry point of fingertip for Oxygen level and Pulse rate measurement. The Temperature probe is well connected with a gland for proper connection. Front Part is made of Clear Fiber glass for view of the screen.

Table. 4 LED Status

Name	Color	Remarks
Low Saturation	Red	SpO2 level < 94
Checking temperature	Blue	Measurement of body temp.

Complete image of hardware setup of pulse oximeter device is given below.

Fig. 9 Hardware setup of the project

6. RESULTS

Fig. 10A Setup Under Testing 1(Comparison)

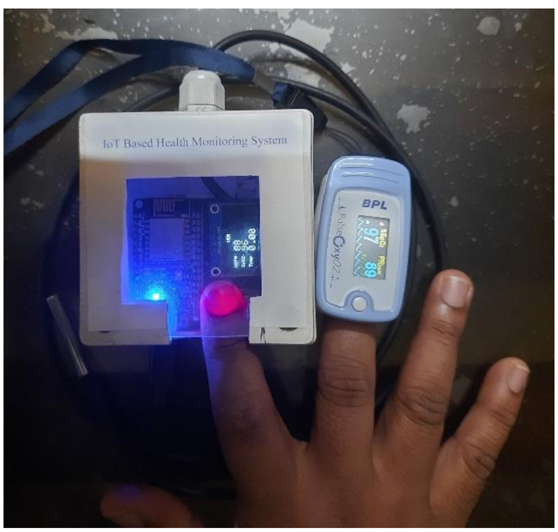


Fig. 10A Setup Under Testing 1(Comparison)

Figure 10A and 10B provides a comparison of our project with the standard available Pulse-Oximeter is showing almost same result.

Table. 5 Results Comparison

Comparison 1		
Hardware Make	SpO2	Heart BPM
Proposed Device	96	89
BPL Medical Technologies Pvt Ltd	97	88
Comparison 2		
Hardware Make	SpO2	Heart BPM
Proposed Device	97	84
Arcatron Mobility Pvt. Ltd.	99	87

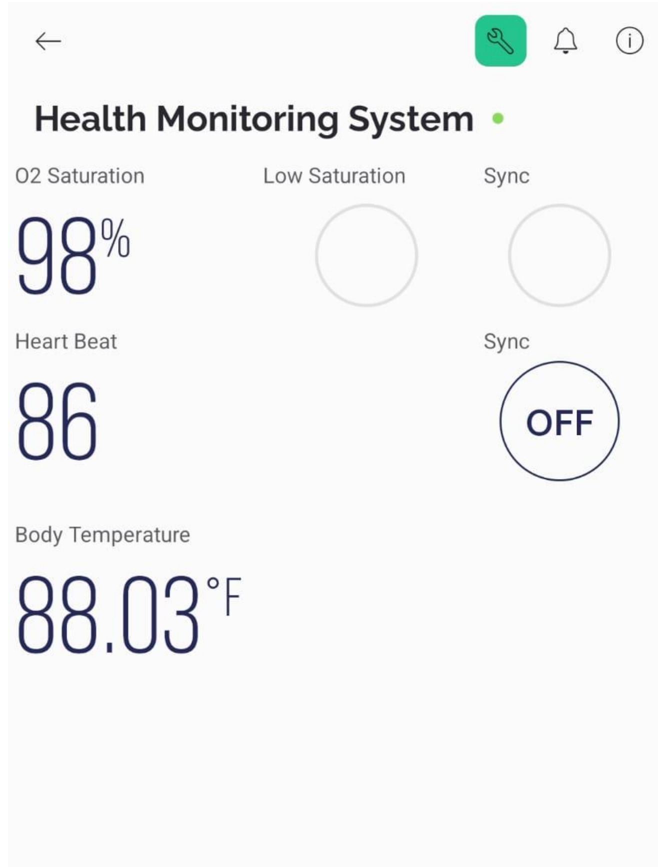


Fig. 11 Blynk User App Interface

Figure 11 shows the live data is available on android application for live monitoring.

Figure 12 shows the web portal for live data monitoring.

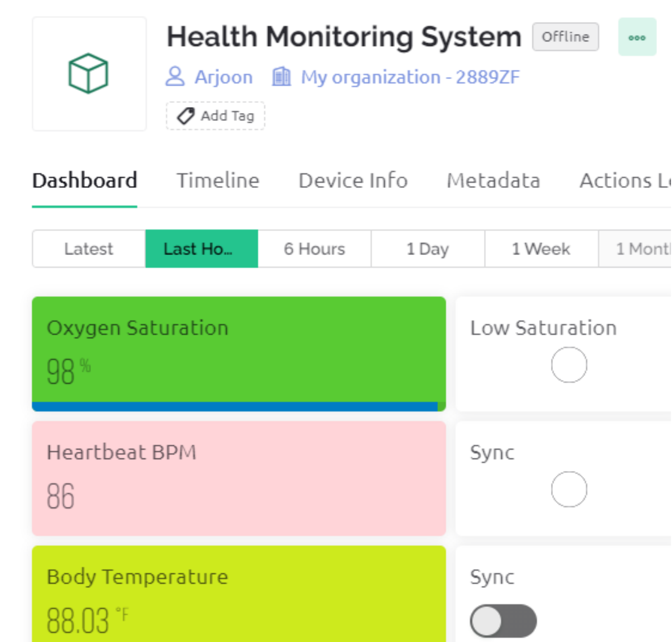


Fig. 12 Blynk User App Interface

7. DISCUSSION & CONCLUSION

To increase the efficiency of modern health care system using automation and IoT this work intends to provide remotely monitoring ability of multiple patients over a single screen, which could be mobile or tab or laptop or desktop. This interactive device data could be shared with the patient's families which would further bring transparency at healthcare institution regarding medical condition of the patients. The Data sent to cloud chosen Wi-Fi as most hospitals in India has Wi-Fi Local Area Network. In case of absence of LAN connectivity GSM Technology will be used to transfer the data to the cloud. For this purpose, only one Wi-Fi Dongle will be used which will be kept in reach of the devices Wi-Fi Range. Individual SIM card in every device would increase the running cost hence one GSM connection is used to provide internet to all the device.

NOVELTY OF OUR WORK- Unlike traditional health monitoring systems, our system integrates remote patient monitoring with real-time data analysis. This combination allows for continuous, real-time health assessments, reducing the need for frequent hospital visits and mitigating the risk of virus transmission. Our approach prioritizes secure communication channels to ensure the confidentiality of sensitive health information. By leveraging advanced encryption methods and secure data transmission protocols, we address the critical need for data privacy in telehealth solutions. While existing IoT health monitoring systems often come with high costs that limit their adoption in developing regions, our system is designed to be affordable. The entire project is made under Rs 5000. The system aids in optimizing the utilization of healthcare resources by alleviating the burden on healthcare facilities. By managing patient data remotely and efficiently, we can improve patient outcomes while ensuring that healthcare resources are used judiciously.

LIMITATIONS - The effectiveness of our system relies heavily on good internet connectivity for real-time data transmission and analysis. In regions with poor internet infrastructure, the system's performance may be compromised. Although designed to be affordable, scaling the system to accommodate a large number of users may create logistical and technical challenges, particularly in terms of data management and server capacity. Although initial testing shows promise, extensive clinical trials and validations are required to fully establish the system's accuracy, reliability, and effectiveness across diverse populations and medical conditions.

8. FUTURE WORK

Checking and comparing data with standard pulse-oximeter found that the accuracy the values are less than 1%.

The data gathered from a patient will be stored in the could for future analysis and to prepare machine learning model so that later on patient's health can be predicted. With this data further research can be done to identify and effect of symptoms of different diseases. Implementing Artificial Intelligence over this data model will further improve the health prediction of any patient just by checking the vitals.

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AUTHORS

Arjoon Chatterjee currently persuing her B.Tech in Electronics & communication Engineering from Institute of Engineering & Management, Kolkata, India. His areas of interest are IoT, Embedded Systems, Health Monitoring System etc.

Corresponding Author e-mail: arjoonchatterjee@gmail.com

Ayan Ghosh currently persuing her B.Tech in ECE from Institute of Engineering & Management, Kolkata, India.

E-mail: ayang8702@gmail.com

Abhishek Kumar currently persuing her B.Tech in ECE from Institute of Engineering & Management, Kolkata, India.

E-mail: abhishekkumar0192@gmail.com

Prashant Kumar Tiwari currently persuing her B.Tech in ECE from Institute of Engineering & Management, Kolkata, India.

E-mail: tiwariprashant250@gmail.com

Priyotosh Garai currently persuing her B.Tech in ECE from Institute of Engineering & Management, Kolkata, India.

Email: priyotoshgorai12032002@outlook.com

Somya Singh currently persuing her B.Tech in Electronics & communication Engineering from Institute of Engineering & Management, Kolkata, India.

E-mail: singhsomya1502@gmail.com

Malay Ganguly Presently he is working as a professor in the Department of Electronics & communication Engineering of, Institute of Engineering & Management, Kolkata, India.

E-mail: malay.ganguly@iem.edu.in

Suchismita Banerjee currently persuing her B.Tech in ECE from RCC Institute of Information Technology in West Bengal, India. She has completed her high school from Aditya Academy Senior Secondary. She has her arena of interest in full stack development and coding with C++ and JAVA. She is presently in her final semester. She has delved to fathom cyber security as an analyst and is currently working as an Intern at PWC.

E-mail: suchismitabanerjee15@gmail.com

Shinjini Mukherjee received her BTech degree from RCC Institute of Information Technology, West Bengal, India in 2020. She is currently working as a Developer at Tata Consultancy Services Limited. Her areas of interest are Renewable Energy, Energy Storage Systems, IoT, Embedded Systems, User Interface Development etc.

E-mail: sudiptasarkar400@gmail.com

Ashoke Mondal did his BE in Electrical Engineering in the year 1986. from BE College (Presently IIEST) and his ME and PhD in Electronics Engineering from Jadavpur University in 1988 and 2005 respectively. He was associated with the School of Energy Studies at Jadavpur University. He worked in the industry for 17 years. He has a teaching experience of 15 years. He designed and developed several SPV systems. Presently he is working as a professor in the Department of Electronics & communication Engineering of RCC Institute of Information Technology, Kolkata.

E-mail: ashoke.mondal@gmail.com